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Characterization of Rainfed pigeonpea Growing Regions based on Soil, Climate, Crop and Socio-economic Parameters

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ABSTRACT : An agro-economic inventory and characterization (Soil resources, rainfall characteristics, pigeonpea productivity and clientele socio-economic parameters) was conducted in 864 farmers fields in 48 blocks in 16 leading rainfed pigeonpea districts across 10 Agro-eco sub regions (4.3, 4.4, 6.1, 6.2, 6.3, 6.4, 7.2, 10.2, 10.3 and 10.4) covering five states in India. An attempt has been made to assess the productivity of rained pigeonpea by integrating the data on soils, climate, crop and socio-economic parameters. Regression analysis indicated a significant influence of rainfall and its distribution on the productivity of pigeonpea. Small farmers' attained highest benefit-cost ratios of 2.57 under wet semi-arid and 2.10 under dry semi-arid situation in alluvial soils. Medium farmers attained a maximum benefit–cost ratio of 2.75 under wet semi-arid climate and 2.68 under dry semi-arid situation in alluvial soils. Large farmers attained a maximum benefit–cost ratio of 2.77 under wet semi-arid and 2.22 under dry semi-arid situations in alluvial soils. In all climatic situations, medium farmers have attained a higher yield, net returns and benefit-cost ratio compared to other categories of farmers. Fatehpur, Banda, Hamirpur, Yavatmal, Amaravati and Chindwara districts were delineated as high productivity efficiency zones for rainfed pigeonpea.

Keywords: Rainfed pigeonpea, soil resources, rainfall, productivity assessment

Among different pulses, pigeonpea is grown in an area of 3.6 million ha (15.5%) and contributes about 2.7 million tons (18.6%) of the production. 94.5 % area of pigeonpea is rainfed. Pigeon pea is grown in 302 districts and is concentrated in the states of Maharashtra (29.1% of the total area under pulses), Uttar Pradesh (13.9%), Karnataka (12.2%), Gujarat (11.4%), Madhya Pradesh (11.4%) and Andhra Pradesh (10%). Together they contribute about 87 % of pigeonpea production with varying levels of productivity ranging between 383 and 1134 kg ha^{-1}. The national average productivity of pigeonpea crop is 747 kg ha^{-1}. A comparison of these levels of productivity with those of the various states indicates much scope for improvement in the productivity levels.

Although the country has made rapid strides in food grain production, yet the production and productivity of pulses has remained static and have indicated a decline during some years in the past five decades. In view of the deficiency in pulse production, the Govt. of India has been importing pulses every year to meet the requirement. The import in 1996-97 was 21,200 tonnes at a cost of Rs.52 crores. If similar situation prolongs, it will further widen the gap between demand and supply of pulses, thus causing either dependence on import at a huge cost or poor dietary standard leading to several health hazards.

The low productivity of pigeonpea is due to aberrant weather conditions and poor soil fertility, poor crop management under biotic and abiotic stresses, and due to various socio-economic constraints. Hence, there is a need to properly evaluate these factors by characterizing the different resources. It is essential to assess land, climate and soil resources and socio-economic factors causing low levels of productivity of the two pulses. An evaluation of socio-economic factors and climatic limitations and integration with soil resources with yields attained by small, medium and large farmers in different targeted districts has been made in the study. Areas which

are potential for pigeonpea in different targeted districts have been identified based on the characterization of soil, climate, crop and socio-economic parameters of pigeonpea growing regions in the country.

Materials and Methods

The information on soil, rainfall, productivity and socio-economic resources have been collected and characterized for assessing the constraints for low productivity of pigeonpea (Maruthi Sankar *et al.,* 2003). An agro-economic survey was conducted in 16 targeted districts which are leading in pigeonpea for area and production under different soil and climatic situations in Uttar Pradesh, Madhya Pradesh, Maharastra, Karnataka and Andhra Pradesh states. Three blocks in each district and 3 villages in each block which are leading in area and production have been identified for field survey. In each village, 6 farmers comprising of 2 large farmers with an area of > 10 acres ; 2 medium farmers with an area of 5 to 10 acres ; and 2 small farmers with an area of < 5 acres have been contacted with a detailed questionnaire and information on different socio-economic parameters, size of holding, yield of chickpea attained, cost of cultivation incurred, problems faced by farmers for cultivation of chickpea have been collected for assessing the reasons for low productivity of chickpea under different agro-ecological sub-regions in the country. A total number of 864 pigeonpea growing farmers were contacted with a questionnaire in the socio-economic survey in the study.

The districts of pigeonpea identified for field survey are in 10 different agro-ecological sub regions and are chosen based on area and production of pigeonpea. The agro-economic survey has been conducted in 16 districts covering a 864 farmers in 5 states. The agro-ecological sub regions where the targeted districts of pigeonpea are located are AESR 4.3 (Kanpur and Fatehpur), 4.4 (Banda and Hamirpur), 6.1 (Raichur), 6.2 (Bidar, Gulbarga and Latur), 6.3 (Yavatmal, Amravati), 6.4 (Dharwad), 7.2 (Khammam, Ranga Reddy) and 10.2 (Nagpur), 10.3 (Sidhi) and 10.4 (Chhindwara). The soils of targeted districts in which pigeonpea is grown are alluvial soils in Kanpur, Fatehpur, Banda and Hamirpur ; medium black soils in Latur, Raichur, Gulbarga, Dharwad and Yavatmal ; deep black soils in Chhindwara, Sidhi, Amaravati, Bidar and Nagpur ; shallow red soils in Ranga Reddy ; and deep red soils in Khammam district. The districts have shallow red, deep red, medium black, deep black and alluvial soils with varying soil properties. The different climatic situations existing in the targeted districts are dry semi-arid (500 – 750 mm) in Fatehpur, Banda, Hamirpur, Amaravati, Latur, Raichur and Gulbarga ; wet semi-arid (750 – 1000 mm) in Ranga Reddy, Chhindwara, Kanpur, Bidar and Dharwad ; and dry sub-humid (1000 – 1250 mm) in Khammam, Sidhi, Yavatmal and Nagpur.

Regression analysis of changes in area, production and yield of pigeonpea

The changes in area, production and yield of pigeonpea during 1990 to 1999 have been measured with regression models of variables over time (Draper and Smith, 1998). The regression coefficients, coefficient of determination (R^2) and prediction error (s) of area, production and yield are given in Table 1. Based on predictability of changes, the changes that have occurred in area of pigeonpea were significant in Hamirpur, Raichur, Bidar, Latur, Yavatmal, Dharwad, Ranga Reddy and Sidhi. Similarly, the changes in production of pigeonpea were significant in Kanpur, Gulbarga and Yavatmal; and the changes in pigeonpea yield were found to be significant in Gulbarga. The predictability of area ranged from 0.03 (Gulbarga) to 0.80 (Latur); production from 0.01 (Khammam and Sidhi) to 0.60 (Kanpur); and yield from 0.01 (Khammam and Ranga Reddy) to 0.49 (Gulbarga). The estimates of error ranged from 0.8 (Banda) to 51.8 (Gulbarga) for area ('000 ha); 2.6 (Khammam) to 53.3 (Gulbarga) for production ('000 tons); and 79 (Ranga Reddy) to 900 (Kanpur) for yield (kg ha^{-1}).

Table 1. Regression models of changes in area, production and yield in pigeonpea

AESR	District	Variable	A, P, Y in 1990	A, P, Y in 1999	Regression model	R^2	σ
4.3	Kanpur # 1	Area	16.68	17.90	A = 27.101 – 1.174 T	0.15	6.8
		Production6	2.65	33.80	P = 56.603 – 4.808 T	0.60*	9.0
		Yield	3756	1888	Y = 2564.300 – 191.570 T	0.20	900.0
	Fatehpur # 2	Area	14.28	17.00	A = 24.901 – 1.066 T	0.17	6.3
		Production	34.57	35.00	P = 31.583 + 0.310 T	0.07	2.9
		Yield	2421	2059	Y = 1457.000 + 76.514 T	0.10	625.0
4.4	Banda # 1	Area	28.69	28.00	A = 28.766 – 0.184 T	0.20	0.8
		Production	48.00	49.00	P = 35.394 + 2.079 T	0.25	8.4
		Yield	1672	1750	Y = 1227.200 + 84.165 T	0.28	316.8
	Hamirpur # 1	Area	23.00	15.40	A = 23.384 – 0.956 T	0.67*	1.7
		Production	32.00	25.40	P = 29.069 – 0.354 T	0.02	5.3
		Yield	1367	1649	Y = 1205.300 + 53.488 T	0.27	204.5
6.1	Raichur	Area	40.87	13.20	A = 42.628 – 2.530 T	0.70**	9.6
		Production	9.01	1.70	P = 9.420 – 0.294 T	0.08	3.2
		Yield	220	129	Y = 201.810 + 15.013 T	0.10	153.8
6.2	Bidar # 1	Area	41.69	47.10	A = 40.874 + 1.171 T	0.65*	2.0
		Production	20.91	35.70	P = 18.410 + 2.316 T	0.25	9.6
		Yield	502	758	Y = 462.220 + 34.728 T	0.15	193.2
	Gulbarga	Area	250.07	285.00	A = 214.170 + 2.725 T	0.03	51.8
		Production	93.00	257.00	P = 21.121 + 15.450 T	0.46*	53.3
		Yield	373	902	Y = 163.460 + 52.745 T	0.49*	174.2
	Latur	Area	69.30	28.90	A = 78.047 – 5.743 T	0.80**	9.0
		Production	14.10	14.80	P = 19.513 – 0.475 T	0.04	7.8
		Yield	203	512	Y = 232.870 + 30.509 T	0.23	176.9
6.3	Yavatmal	Area	88.60	116.60	A = 92.133 + 2.967 T	0.49*	9.6
		Production	55.00	114.70	P = 61.713 + 5.361 T	0.44*	19.4
		Yield	621	984	Y = 665.560 + 29.949 T	0.29	151.3
	Amravati	Area	83.10	86.30	A = 84.927 + 0.195 T	0.04	3.2
		Production	50.90	92.00	P = 52.553 + 3.645 T	0.35	16.0
		Yield	613	1066	Y = 615.070 + 41.145 T	0.38	169.0
6.4	Dharwad	Area	16.51	1.80	A = 23.215 – 1.719 T	0.71**	3.6
		Production	3.01	1.40	P = 9.162 – 0.594 T	0.28	3.2
		Yield	182	778	Y = 309.910 + 26.197 T	0.23	151.3
7.2	Khammam	Area	27.52	26.00	A = 28.055 – 0.287 T	0.26	1.4
		Production	14.00	15.00	P = 12.779 – 0.091 T	0.01	2.6
		Yield	501	577	Y = 450.500 + 2.150 T	0.01	84.6
	Ranga Reddy	Area	24.00	37.00	A = 20.571 + 2.143 T	0.79**	2.6
		Production	11.00	18.00	P = 7.571 + 1.036 T	0.37	3.2
		Yield	458	486	Y = 387.620 + 2.359 T	0.01	79.2

10.2	Nagpur	Area	55.60	52.40	A = 55.000 – 0.267 T	0.24	1.4
		Production	31.30	38.80	P = 25.753 + 0.558 T	0.03	10.2
		Yield	563	740	Y = 461.370 + 13.692 T	0.05	187.7
10.3	Sidhi # 3	Area	30.20	33.00	A = 28.328 + 0.583 T	0.63*	1.2
		Production	21.60	17.60	P = 17.156 + 0.007 T	0.01	3.2
		Yield	715	533	Y = 594.650 – 9.171 T	0.08	90.3
10.4	Chhindwara # 3	Area	28.30	27.60	A = 27.267 – 0.253 T	0.23	1.4
		Production	53.50	43.80	P = 41.203 – 0.712 T	0.05	9.0
		Yield	1890	1587	Y = 1505.000 – 12.889 T	0.02	309.8

* & ** indicate significance at 5 & 1% level A: Area ('000 ha) P: Production ('000 tons)Y =Yield (kg ha^{-1}) T: Years # 1: Data available upto 1996 # 2: Data available upto 1997 # 3: Data available upto 1998

Regression models of pigeonpea yield through rainfall

Regression models of yield through rainfall have been calibrated for assessing the influence of rainfall on yield using pigeonpea yield and rainfall of each season. The mean rainfall ranged from 546 mm at Fatehpur to 1103 mm at Khammam, while mean yield ranged from 284 kg ha^{-1} in Raichur to 1801 kg ha^{-1} in Fatehpur. The estimates of predictability have ranged from 0.01 (Latur, Yavatmal and Banda) to 0.28 (Hamirpur) and are not significant. Based on the regression models, the prediction error has ranged from 146 kg ha^{-1} in Fatehpur to 557 kg ha^{-1} in Gulbarga. The estimates of regression coefficients, coefficient of determination (R^2) and prediction error (s) of pigeonpea yield through rainfall are given in Table 2.

Table 2. Regression models of yield of pigeonpea in targeted districts

AESR	District	Rainfall (mm)	Yield (kg ha^{-1})	Regression model	R^2	σ
4.3	Kanpur	1063	1798	Y = 3624.20 – 1.817 RF	0.12	182.3
	Fatehpur	546	1801	Y = 1154.60 + 1.212 RF	0.08	146.4
4.4	Banda	645	1563	Y = 1532.50 + 0.054 RF	0.01	320.4
	Hamirpur	572	1419	Y = 1675.10 – 0.478 RF	0.28	228.0
6.1	Raichur	665	284	Y = 189.57 + 0.141 RF	0.04	213.2
6.2	Bidar	916	601	Y = 522.66 + 0.085 RF	0.02	353.4
	Gulbarga	734	454	Y = 74.19 + 0.526 RF	0.20	557.0
	Latur	703	401	Y = 466.62 – 0.096 RF	0.01	148.8
6.3	Yavatmal	980	830	Y = 884.32 – 0.054 RF	0.01	222.0
	Amravati	762	841	Y = 696.28 + 0.158 RF	0.02	190.4
6.4	Dharwad	873	454	Y = 194.61 + 0.297 RF	0.10	171.6
7.2	Khammam	1103	462	Y = 289.44 + 0.159 RF	0.21	213.2
	Ranga Reddy	867	397	Y = 428.77 – 0.040 RF	0.02	252.8
10.2	Nagpur	953	537	Y = 649.17 – 0.116 RF	0.02	201.6
10.3	Sidhi	1046	549	Y = 459.94 + 0.085 RF	0.08	306.3
10.4	Chhindwara	847	1441	Y = 1707.40 – 0.307 RF	0.03	171.6

Y: Yield (kg ha^{-1}) RF: Rainfall (mm)

Relative spread and yield indices of pigeonpea

Using the total cultivable area, area under pigeonpea and yield of pigeonpea in a district, the relative spread and yield indices are given in Table 3. The total cultivable area has ranged from 3,25,499 ha in Ranga Reddy to 15,69,700 ha in Kanpur. The pigeonpea area has ranged between 7800 ha in Dharwad to 24,77,000 ha in Gulbarga. The yield of pigeonpea was highest in Fatehpur (1801 kg ha^{-1}), while it was lowest in Raichur (284 kg ha^{-1}) compared to all India productivity of 797 kg ha^{-1}. The relative spread index ranged from 63% in Kanpur under wet semi-arid alluvial soils (1063 mm of rainfall) to 712% in Gulbarga under dry semi-arid medium black soils (734 mm of rainfall). The relative yield index ranged from 36% under dry semi-arid medium black soils of Raichur (665 mm of rainfall) to 226% under in alluvial soils under dry semi-arid climate at Fatehpur (546 mm of rainfall) and wet semi-arid climate at Kanpur (1063 mm of rainfall).

Table 3. Relative spread and yield indices of pigeonpea in different targeted districts

AESR	District	Soil type	Rainfall (mm)	Total cultivable area (ha)	Pigeonpea area (ha)	Yield (kg ha^{-1})	Relative spread	Relative Yield Index
4.3	Kanpur	Alluvial	1063	1569700	24370	1798	63	226
	Fatehpur	Alluvial	546	386400	22450	1801	237	226
4.4	Hamirpur	Alluvial	572	549300	20250	1419	150	178
	Banda	Alluvial	645	591700	28040	1563	193	196
6.1	Raichur	Medium black	665	644000	20400	284	129	36
6.2	Latur	Medium black	703	715000	63800	401	364	50
	Gulbarga	Medium black	734	1420000	247700	454	712	57
	Bidar	Deep black	916	464000	48300	601	425	75
6.3	Yavatmal	Medium black	980	980000	120800	830	503	104
	Amravati	Deep black	762	1024000	85200	841	340	106
6.4	Dharwad	Medium black	873	464000	7800	454	69	57
7.2	Ranga Reddy	Shallow red	867	325499	35406	397	444	50
	Khammam	Deep red	1103	471380	26392	462	228	58
10.2	Nagpur	Deep black	953	592000	53300	537	367	67
10.3	Sidhi	Deep black	1046	377053	32600	549	353	69
10.4	Chhindwara	Deep black	847	495929	25200	1441	207	181
	All India			142021000	3480000	797		

Grouping of pigeonpea targeted districts

A grouping of pigeonpea districts is made based on relative spread and yield indices given in Table 4. Based on the grouping, it was found that Fatehpur (AESR 4.3), Banda and Hamirpur (AESR 4.4), Yavatmal and Amravati (AESR 6.3) and Chhindwara (AESR 10.4) have a high spread and high yield index. Latur, Gulbarga and Bidar (AESR 6.2), Khammam and Ranga Reddy (AESR 7.2), Nagpur (AESR 10.2) and Sidhi (AESR 10.3) have a high spread and medium yield index. Dharwad (AESR 6.4) has medium spread and medium yield index; Kanpur (AESR 4.3) has medium spread and high yield index ; and Raichur (6.1) has high spread and low yield index.

Table 4. Grouping of pigeonpea districts based on relative spread and yield indices

Relative spread index	Relative yield index		
	High (> 90 %)	Medium (45 – 90 %)	Low (< 45 %)
High	4.3 – Fatehpur 4.4 – Banda, Hamirpur 6.3 – Yavatmal, Amravati 10.4 – Chhindwara	6.2 – Latur, Gulbarga, Bidar 7.2 – Khammam, Ranga Reddy 10.2 - Nagpur 10.3 – Sidhi	6.1 – Raichur
Medium (45 – 90 %)	4.3 – Kanpur	6.4 – Dharwad	

Information on soil parameters

Information on different soil parameters has been collected for each of the 48 blocks. The block wise details of soil parameters and length of growing period in different districts of pigeonpea are given in Table 5.

Soil type

Five soil types were found in different blocks viz., Alluvial soils in different blocks of Kanpur and Fatehpur under AESR 4.3; Banda and Hamirpur under AESR 4.4 in Uttar Pradesh; Medium black soils in different blocks of Raichur (AESR 6.1), Gulbarga (AESR 6.2) and Dharwad (AESR 6.4) in Karnataka; and Latur (AESR 6.2) and Yavatmal (AESR 6.4) in Maharashtra; Deep black soils in different blocks of Bidar (AESR 6.2) district in Karnataka; Amravati (AESR 6.3) and Nagpur (AESR 10.2) in Maharastra; Sidhi (AESR 10.3) and Chhindwara (10.4) in Madhya Pradesh; Shallow red soils in different blocks of Ranga Reddy (AESR 7.2) in Andhra Pradesh; and Deep red soils in different blocks of Khammam (AESR 7.2) in Andhra Pradesh.

Soil depth

The soils with varying depth found in different blocks viz., extremely shallow soils were found in Pusad block of Yavatmal in Maharastra while very shallow soils existed in Chhindwara in Madhya Pradesh; Yavatmal block of Yavatmal district and Narkhed block of Nagpur in Maharashtra; and Tandur block of Ranga Reddy in Andhra Pradesh; and shallow soils were found in Dharwad in Karnataka; Sidhi in Madhya Pradesh; Bhadrachalam block of Khammam district, Basheerbad and Peddemul blocks of in Ranga Reddy.

Slightly deep soils were found in all the three blocks of Raichur and Gulbarga Karnataka, and Latur and Amravati in Maharashtra; while moderately deep soils were found in all the three blocks of Bidar in Karnataka; and Khammam block of Khammam in Andhra Pradesh; and deep soils were found in all the three blocks of Kanpur, Fatehpur, Banda and Hamirpur in Uttar Pradesh; Wani block of Yavatmal, Saoner and Hingana of Nagpur in Maharashtra; Madhira block of Khammam in Madhya Pradesh.

Soil texture

Six soil textures viz., silt loam, silt clay, clay loam, clay, loamy and sandy loam were found in different blocks of targeted districts of pigeonpea and are as follows:

Clay texture in Khammam and Ranga Reddy in Andhra Pradesh ; Latur district, Yavatmal and Wani blocks of Yavatmal district and Hingana block of Nagpur in Maharastra ; and clay loam texture in Raichur, Bidar, Dharwad and Gulbarga in Karnataka ; Amravati in Maharastra.

Silt loam texture in Malasa block of Kanpur, Bahra block of Fatehpur, Bharokhar block of Banda and Muskara block of Hamirpur in Uttar Pradesh ; and silt clay texture in Amaraudh and Ghatampur blocks of Kanpur; Malaw and Amoli blocks of Fatehpur; Tindawari and Jaspura blocks of Banda; and Khurara and Summerpur blocks of Hamirpur in Uttar Pradesh ; and

Loamy texture was found in Pusad block of Yavatmal and Narkhed and Saoner blocks of Nagpur in Maharashtra; and sandy loam texture in Sidhi and Chhindwara in Madhya Pradesh.

Soil reaction (pH)

The soil reaction as measured by pH value was found to be suitable with a range of 6.5 to 8.5 in all the blocks of pigeonpea except Pusad block of Yavatmal, Hingana

block of Nagpur in Maharashtra where the reaction was alkaline; and Sidhi and Chirangi blocks of Chhindwara in Madhya Pradesh where it was acidic.

Soil nitrogen

Low soil N (150 to 250 kg ha^{-1}) in all the three blocks of Kanpur, Fatehpur, Banda and Hamirpur in Uttar Pradesh; Khammam and Ranga Reddy in Andhra Pradesh ; Udgir block of Latur, Amravati and Chandur bazaar blocks of Amravati in Maharashtra ; Sidhi in Madhya Pradesh ; and medium soil N (250 to 400 kg ha^{-1}) in all the three blocks in Raichur, Bidar, Gulbarga and Dharwad in Karnataka ; Yavatmal, Nagpur, Latur and Chakur blocks of Latur, and Anjangaon block of Amravati in Maharastra; and Chhindwara in Madhya Pradesh.

Soil phosphorus

Very low soil P (< 5 kg ha^{-1}) was found in Latur and Chakur blocks of Latur in Maharashtra; while Low soil P (5 to 10 kg ha^{-1}) was found in all the three blocks of Kanpur, Fathepur, Banda and Hamirpur in Uttar Pradesh ; Amravati, Yavatmal and Nagpur district and Udgir block of Latur in Maharashtra; Khammam and Ranga Reddy in Andhra Pradesh ; and medium soil P (10 to 20 kg ha^{-1}) in all the three blocks of Raichur, Bidar, Gulbarga and Dharwad in Karnataka ; Chhindwara and Sidhi in Madhya Pradesh.

Soil potassium

Medium soil K (250 to 400 kg ha^{-1}) in all the three blocks of Kanpur, Fatehpur, Banda and Hamirpur in Uttar Pradesh ; Amravati, Yavatmal and Nagpur districts and Chakur block of Latur in Maharastra ; Khammam in Andhra Pradesh ; while High soil K (400 to 600 kg ha^{-1}) in all the three blocks of Ranga Reddy in Andhra Pradesh ; Raichur, Bidar, Gulbarga and Dharwad in Karnataka ; Chhindwara and Sidhi in Madhya Pradesh ; and Very high soil K (more than 600 kg ha^{-1}) was found in Latur and Udgir blocks of Latur in Maharastra.

Length of growing period

Five lengths of growing period (LGP) viz., 90 to 120 days, 90 to 150 days, 120 to 150 days, 150 to 180 days and 180 to 210 days were prevailing in different blocks viz., 90 to 120 days in all the three blocks of Raichur district and Hubli and Kalghatghi blocks of Dharwad in Karnataka; Sidhi and Chirangi blocks of Sidhi district, Pandhurna block of Chhindwara; 90 to 150 days in Deosar block of Sidhi, Saunsar block of Chhindwara in Madhya Pradesh; 120 to 150 days in all the three blocks of Kanpur, Fatehpur, Banda and Hamirpur in Uttar Pradesh; Bidar and Gulbarga in Karnataka; Latur and Amravati and Pusad block of Yavatmal in Maharashtra; and Ranga Reddy in Andhra Pradesh; 150 to 180 days in all the three blocks of Khammam in Andhra Pradesh; Nagpur, Yavatmal and Wani blocks of Yavatmal in Maharashtra; and Parasia block of Chhindwara in Madhya Pradesh; and 180 to 210 days in Dharwad block of Dharwad district in Karnataka.

Table 5. Block-wise details of soil parameters and length of growing period. (LPG) OF pigeonpea

Block	Soil type	Texture	Soil depth (cm)	Soil reaction (pH)	Available soil N, P, K (kg ha^{-1})			LGP (days)
					N	P	K	
AESR : 4.3 – Kanpur, Fatehpur								
Malasa	Alluvial	Silty loam	> 100	6.5-8.5	150-200	5-10	250-400	120-150
Amaraudha	Alluvial	Silty clay	> 100	6.5-8.5	150-200	5-10	250-400	120-150
Ghatampur	Alluvial	Silty clay	> 100	6.5-8.5	150-200	5-10	250-400	120-150
Malaw	Alluvial	Silty clay	> 100	6.5-8.5	150-200	5-10	250-400	120-150
Amoli	Alluvial	Silty clay	> 100	6.5-8.5	150-200	5-10	250-400	120-150
Bahua	Alluvial	Silty loam	> 100	6.5-8.5	150-200	5-10	250-400	120-150
AESR : 4.4 – Banda, Hamirpur								
Bharokhar	Alluvial	Silty loam	> 100	6.5-8.5	150-200	5-10	250-400	120-150
Tindawari	Alluvial	Silty clay	> 100	6.5-8.5	150-200	5-10	250-400	120-150
Jaspura	Alluvial	Silty clay	> 100	6.5-8.5	150-200	5-10	250-400	120-150
Muskara	Alluvial	Silty loam	> 100	6.5-8.5	150-200	5-10	250-400	120-150

Kurara	Alluvial	Silty clay	> 100	6.5-8.5	150-200	5-10	250-400	120-150
Summerpur	Alluvial	Silty clay	> 100	6.5-8.5	150-200	5-10	250-400	120-150
AESR : 6.1 – Raichur								
Raichur	Medium black	Clay loam	50-75	6.5-8.5	250-400	10-20	400-600	90-120
Devadurg	Medium black	Clay loam	50-75	6.5-8.5	250-400	10-20	400-600	90-120
Manvi	Medium black	Clay loam	50-75	6.5-8.5	250-400	10-20	400-600	90-120
AESR : 6.2 – Bidar, Gulbarga, Latur								
Bhalki	Deep black	Clay loam	75-100	6.5-8.5	250-400	10-20	400-600	120-150
Basava-kalyan	Deep black	Clay loam	75-100	6.5-8.5	250-400	10-20	400-600	120-150
Aurad	Deep black	Clay loam	75-100	6.5-8.5	250-400	10-20	400-600	120-150
Gulbarga	Medium black	Clay loam	50-75	6.5-8.5	250-400	10-20	400-600	120-150
Jawargi	Medium black	Clay loam	50-75	6.5-8.5	250-400	10-20	400-600	120-150
Aland	Medium black	Clay loam	50-75	6.5-8.5	250-400	10-20	400-600	120-150
Latur	Medium black	Clay	50-75	6.5-8.5	250-400	< 5	> 600	120-150
Chakur	Medium black	Clay	50-75	6.5-8.5	250-400	< 5	250-400	120-150
Udgir	Medium black	Clay	50-75	6.5-8.5	150-200	5-10	> 600	120-150
AESR : 6.3 – Amravati, Yavatmal								
Amravati	Deep black	Clay loam	50-75	6.5-8.5	150-200	5-10	250-400	120-150
Chandur-bazar	Deep black	Clay loam	50-75	6.5-8.5	150-200	5-10	250-400	120-150
Anjangaon	Deep black	Clay loam	50-75	6.5-8.5	250-400	5-10	250-400	120-150
Yavatmal	Medium black	Clay	10-25	6.5-8.5	250-400	5-10	250-400	150-180
Wani	Medium black	Clay	> 100	6.5-8.5	250-400	5-10	250-400	150-180
Pusad	Medium black	Loamy	10-25	> 8.5	250-400	5-10	250-400	120-150
AESR : 6.4 – Dharwad								
Dharwad	Medium black	Clay loam	25-50	6.5-8.5	250-400	10-20	400-600	180-210
Hubli	Medium black	Clay loam	25-50	6.5-8.5	250-400	10-20	400-600	90-120
Kalghatghi	Medium black	Clay loam	25-50	6.5-8.5	250-400	10-20	400-600	90-120
AESR : 7.2 – Khammam, Ranga Reddy								
Badrachalam	Deep red	Clay	25-50	6.5-8.5	150-200	5-10	250-400	150-180
Khammam	Deep red	Clay	75-100	6.5-8.5	150-200	5-10	250-400	150-180
Madhira	Deep red	Clay	> 100	6.5-8.5	150-200	5-10	250-400	150-180
Tandur	Shallow red	Clay	10-25	6.5-8.5	150-200	5-10	400-600	120-150
Basheerabad	Shallow red	Clay	25-50	6.5-8.5	150-200	5-10	400-600	120-150
Peddemul	Shallow red	Clay	25-50	6.5-8.5	150-200	5-10	400-600	120-150
AESR : 10.2 – Nagpur								
Narkhed	Deep black	Loamy	10-25	6.5-8.5	250-400	5-10	250-400	150-180
Saoner	Deep black	Loamy	> 100	6.5-8.5	250-400	5-10	250-400	150-180
Hingna	Deep black	Clay	> 100	> 8.5	250-400	5-10	250-400	150-180
AESR : 10.3 - Sidhi								
Sidhi	Deep black	Sandy loam	25-50	< 6.5	150-200	10-20	400-600	90-120
Chirangi	Deep black	Sandy loam	25-50	< 6.5	150-200	10-20	400-600	90-120
Deosar	Deep black	Sandy loam	25-50	< 6.5	150-200	10-20	400-600	90-150
AESR : 10.4 – Chhindwara								
Saunsar	Deep black	Sandy loam	10-25	6.5-8.5	250-400	10-20	400-600	90-150
Pandhurna	Deep black	Sandy loam	10-25	< 6.5	250-400	10-20	400-600	90-120
Parasia	Deep black	Sandy loam	10-25	< 6.5	250-400	10-20	400-600	150-180

Table 6. Block wise rainfall (mm) in pigeonpea growing districts during 1990 to 2000

AESR	District	Block	Minimum	Maximum	Mean	CV (%)
4.3	Kanpur	Kanpur	572.8	1556.3	774	29.8
	Fatehpur	Fatehpur	307.6	796.2	546	22.5
4.4	Banda	Banda	343.3	1525.6	662	53.8
	Hamirpur	Hamirpur	182.8	1009.0	574	43.8
6.1	Raichur	Raichur	471.4	958.6	711	26.7
	Devadurg		299.1	959.2	726	35.6
	Manvi		248.6	965.3	557	53.4
6.2	Latur	Latur	340.9	1069.0	701	35.0
	Chakur		405.3	994.4	619	30.1
	Udgir		359.3	1289.8	715	39.2
	Gulbarga	Gulbarga	465.8	868.2	625	22.3
	Jawargi		541.1	945.7	743	21.8
	Aland		501.9	1078.7	718	27.8
	Bidar	Bhalki	502.4	1352.2	868	36.9
	Basava Kalyan		439.6	900.8	696	24.1
	Aurad		583.9	1223.8	890	26.6
6.3	Amravati	Amravati	645.9	1238.2	941	27.1
	Chandur-bazar		446.2	1016.3	670	33.2
	Anjagaon		301.2	728.7	598	30.1
	Yavatmal	Yavatmal	493.5	1327.1	980	29.6
	Wani		886.1	1149.1	1009	10.7
	Pusad		481.0	1900.9	1113	45.4
6.4	Dharwad	Dharwad	738.7	1238.6	923	20.0
	Hubli		492.1	1596.1	815	50.7
	Kalghatghi		891.5	1405.5	1082	18.0
7.2	Khammam	Badrachalam	977.0	1617.0	1190	21.1
	Khammam		784.4	1245.8	964	16.9
	Madhira		662.0	1699.0	1077	32.9
	Ranga Reddy	Basheerbad	493.5	1423.2	827	37.4
	Peddemul		517.1	1153.7	817	19.8
	Tandur		505.6	1370.3	869	27.8
10.2	Nagpur	Narkhed	714.4	1186.7	955	16.7
	Saoner		680.8	1231.0	988	21.9
	Hingna		643.2	1765.0	1120	33.4
10.3	Sidhi	Chirangi	565.9	1757.8	929	46.9
	Deosar		508.2	1630.4	968	40.0
	Sidhi		728.4	1747.7	1188	24.6
10.4	Chhindwara	Saunsar	456.5	835.1	669	21.7
	Pandhurna		673.8	1040.7	812	15.5
	Parasia		730.6	1430.5	1057	24.0

Rainfall and its distribution in different blocks

The block-wise annual rainfall has been analyzed for the period 1990 to 2000 and examined for the distribution parameters like minimum, maximum, mean and coefficient of variation of rainfall in each block (Table 6). The mean rainfall has ranged from 546 mm (with a coefficient of variation of 22.5%) in Fatehpur to 1188 mm (with a coefficient of variation of 24.6%) in Sidhi block (Sidhi). Out of 40 blocks, 30 blocks (75 %) were found to have a coefficient of variation of rainfall ranging from 20 to 50 %, while 7 blocks (17.5 %) were found to have less than 20 % coefficient of variation and 3 blocks (7.5 %) have more than 50 % coefficient of variation (Table 7).

Table 7. Classification of different blocks of pigeonpea based on rainfall variation

AESR	District	Climate	Coeffiient of variation (%)		
			< 20	20 - 50	> 50
4.3	Kanpur	Wet semi - arid		Kanpur	
	Fatehpur	Dry semi - arid		Fatehpur	
4.4	Banda	Dry semi – arid			Banda
	Hamirpur	Dry semi – arid		Hamirpur	
6.1	Raichur	Dry semi – arid		Raichur, Devadurg	Manvi
6.2	Latur	Dry semi – arid		Latur, Chakur, Udgir	
	Gulbarga	Dry semi – arid		Gulbarga, Jawargi, Aland	
	Bidar	Dry semi – arid		Basava Kalyan	
		Wet semi – arid		Balki, Aurad	
6.3	Amravati	Dry semi – arid		Chandur-bazar, Anjangaon	
		Wet semi – arid		Amravati	
	Yavatmal	Wet semi – arid		Yavatmal	
		Dry sub – humid	Wani	Pusad	
6.4	Dharwad	Wet semi – arid	Dharwad		Hubli
		Dry sub – humid	Kalghatghi		
7.2	Khammam	Wet semi – arid	Khammam		
		Dry sub – humid		Bhadrachalam, Madhira	
	Ranga Reddy	Wet semi - arid	Peddemul	Basheerabad, Tandur	
10.2	Nagpur	Wet semi – arid	Narkhed	Saoner	
		Dry sub – humid		Hingna	
10.3	Sidhi	Wet semi – arid		Chirangi, Deosar	
		Dry sub – humid		Sidhi	
10.4	Chhindwara	Dry semi – arid		Saunsar	
		Wet semi – arid	Pandhurna		
		Dry sub - humid		Parasia	
		Total	7 (17.5)	30 (75.0)	3 (7.5)

Grouping of blocks based on yield

The grouping of blocks based on yield is given in Table 8. Based on the grouping of blocks for pigeonpea yield, it was found that farmers have attained yield > m + s in 5 (10.4%) blocks viz., Raichur (Raichur)), Pusad (Yavatmal), Pandhurna (Chhindwara), Sidhi and Deosar (Sidhi); Yield < m - s in 3 (6.3%) blocks viz., Yavatmal (Yavatmal), Chirangi (Sidhi), Bahua (Fatehpur) and Saunsar (Chhindwara); and yields lying between m + s and m - s in all the remaining 40 (83.3%) blocks.

Table 8. Grouping of Pigeonpea growing blocks based on mean and standard deviation of yield

AESR	District	μ	σ	Grouping of blocks		
				> μ + σ	μ − σ το μ + σ	< μ − σ
4.3	Kanpur	1504	42		Ghatampur, Amaraudha, Malasa	
	Fatehpur	1521	55		Bahua, Malaw, Amoli	
4.4	Banda	1349	92		Bharokhar, Tindawari, Jaspura	
	Hamirpur	1352	96		Kurara, Summerpur, Muskara	
6.1	Raichur	658	105	Raichur	Devadurg, Manvi	
6.2	Latur	733	131		Latur, Udgir, Chakur	
	Gulbarga	926	110		Gulbarga, Jawargi, Aland	
	Bidar	824	37		B-Kalyan, Aurad, Bhalki	
6.3	Amravati	951	74		Amravati, C-Bazar, Anjangaon	
	Yavatmal	934	102	Pusad	WaniYavatmal	
6.4	Dharwad	250	75		Dharwad, Hubli, Kalghatghi	
7.2	Khammam	881	96		Madhira, Khammam. Bhadrachalam	
	Ranga Reddy	311	113		Tandur, Peddemul. Basheerbad	
10.2	Nagpur	790	190		Narkhed, Saoner, Hingana	
10.3	Sidhi	991	58	Sidhi, Deosar		Chirangi
10.4	Chhindwara	761	62	Pandhurna	Parasia	Saunsar
	Total			5 (10.4)	40 (83.3)	3 (6.3)

Values in parentheses indicate % of blocks falling in the group μ : Mean (kg ha^{-1}) σ : Standard deviation (kg ha^{-1})

Soil, climate and farmer category wise estimates of mean of different variables

The farmer category wise mean pigeonpea yield, net returns and benefit-cost ratio attained and cost of cultivation incurred under each climate and soil are given in Table 9. Small farmers attained the highest benefit-cost ratio of 2.57 under wet semi-arid, followed by 2.10 under dry semi-arid situations in alluvial soils. Similarly, medium farmers attained benefit-cost ratio of 2.75 and 2.68 and large farmers attained 2.77 and 2.22 under these situations respectively. Medium farmers attained a maximum benefit-cost ratio of 1.93 under dry sub-humid climate in deep black soils and 1.15 in deep red soils compared to small and large farmers. In all the climatic situations under medium and deep black soils, large farmers have attained a higher yield and net returns, while medium farmers have attained a higher yield and net returns in alluvial soils.

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Table 9. Soil, climate and farmer category wise mean yield and other variables in pigeonpea growing districts

Soil type	Climate	Small				Medium				Large			
		Y	CC	NR	BC	Y	CC	NR	BC	Y	CC	NR	BC
Alluvial	Dry semi arid	1169	5308	11066	2.10	1551	6157	16432	2.68	1500	6772	14960	2.22
	Wet semi arid	1362	5365	13149	2.57	1646	6236	17148	2.75	1503	6532	14860	2.77
Medium black	Dry semi arid	780	8418	2734	0.34	790	8688	2673	0.31	838	8374	3805	0.42
	Wet semi arid	206	4407	-1106	0.18	250	4607	-728	0.21	288	4743	-756	0.51
Deep black	Dry semi arid	804	10746	1903	0.19	1024	10770	5061	0.47	974	8912	6020	0.67
	Wet semi arid	757	6046	4255	0.87	685	6123	3345	0.66	799	6395	4619	0.84
	Dry sub humid	794	4181	6698	1.67	885	4180	7480	1.93	964	4719	8173	1.76
Shallow red	Wet semi arid	297	8851	-4695	0.49	320	8731	-4132	0.37	316	9732	-4950	0.51
Deep red	Dry sub humid	752	6295	6779	1.09	851	6991	7235	1.15	1040	7911	6940	0.92

Y : Yield (kg/ha) CC : Cost of cultivation (Rs ha^{-1}) NR : Net returns (Rs ha^{-1}) BC : Benefit-cost ratio